The Adriatic Basin Forecasting System: new model and system development

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Abstract

The Adriatic Basin Forecasting System implemented within the framework of the ADRICOSM Partnership (ADRIatic sea integrated COstal areaS and river basin Management system), nested to the operational general circulation model of the Mediterranean Sea, has recently been upgraded both in terms of system design and model parameterizations. The operational forecast is now daily, producing 9 days forecast, and a new near real time quality control has been introduced. From the modeling point of view the system has been upgraded in resolution (vertically from 21 to 31 sigma levels, and horizontally from approximately 1/22° to approximately 1/45°). Realistic fresh water fluxes have been introduced through the surface boundary condition taking into account evaporation, precipitation and river runoff, and the Smolarckiwicz advection scheme has been changed to the MUSCL scheme. The details of these developments will be presented, together with the model validation in delayed and real time mode

Keywords: operational oceanography, numerical models, forecasting system

1. Introduction

The importance of marine forecasting systems for the management of emergencies and the coastal resources is becoming evident for all the end-users of operational oceanography products. Issues such as the management of coastal waters, the response to environmental disasters like oil spill or gas pollution, the support to search and rescue operations at sea, the knowledge of the marine ecosystem evolution connected to physical flow conditions are just some examples of the reasons why investing and developing marine forecasting systems is now mandatory.

The Mediterranean ocean Forecasting System (MFS) (Pinardi et al, 2003) produces analyses and forecasts at low resolution (around 6.5 km, Tonani et al., 2008) and thus downscaling is required if we want to simulate accurately the shelf dynamics. Since April 2003 a nested forecasting system is implemented in the Adriatic Sea (Oddo et al., 2006) and is running operationally once a week at the Istituto Nazionale di Geofisica e Vulcanologia, to produce 9 days forecasts of the main hydrodynamics state variables such as: currents, temperature, salinity, sea level and air-sea fluxes.

Within the last two years the Adriatic Forecasting System (AFS) has undergone some important updates and changes, both form a modeling point of view and from a system point of view. This short paper is going to present these last updates and the results of the new model with particular respect to the comparison with the old model.

2. System design and modelling updates

The first forecast upgrade concerns the forecast cycle. The weekly system (Oddo et al., 2006), operational up to June 2007, used to have the following structure: every week (at Wednesday, day J+1) the numerical model was integrated for 7 days in hindcast mode from mid-day of the previous Tuesday (J-7) to mid-day of the current week's Tuesday (J). Hindcast means a simulation done in the past also with as good as possible atmospheric forcing, i.e., atmospheric state variables analyses. This simulation produced the initial conditions for the forecast starting at J. The numerical model was then integrated in forecast mode for 9 days, i.e., a single deterministic atmospheric forecast was used to force the ocean model. No more hindcast nor forecast was done until the successive week (J+7), when the same chain of operations was repeated.

The new daily system, operational since June 2007, is the combination of a weekly and a daily cycle, and it is structured as follows: every day but Wednesday (for example day J+1) a forecast of 9 days is produced, starting from an initial condition produced by a hindcast of the previous day (J). The hindcast done this way is 'sub-optimal' since the lateral boundary conditions from the Mediterranean model are from a simulation instead than an analysis (combination of model and observations). In order to 'reset' the system to optimal lateral boundary conditions, the system is run in hindcast mode, from noon of day J-7 to noon of day J once a week. This hindcast simulation produces the initial condition for the Wednesday nine-days forecast run.

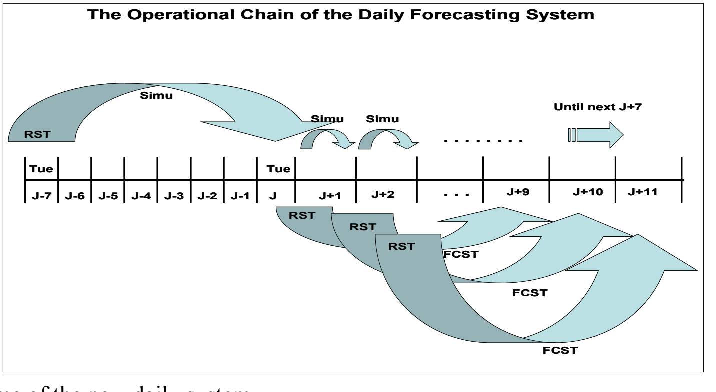

Figure1: Scheme of the new daily system.

The second improvement is the nested model resolution, surface boundary condition, lateral boundary condition and the advection scheme. The model is based on the Princeton Ocean Model (Blumberg and Mellor, 1987) and the old implementation is described in Oddo et al. (2005).

The resolution of the old implementation was about 5 km in the horizontal and 21 sigma-layers on the vertical. In the new implementation the horizontal resolution is about 2.2 km and the vertical is 31 double logarithmic sigma layers. This increase in resolution allows to better represent small scale features and structures which the old model could not capture (see fig. 2).

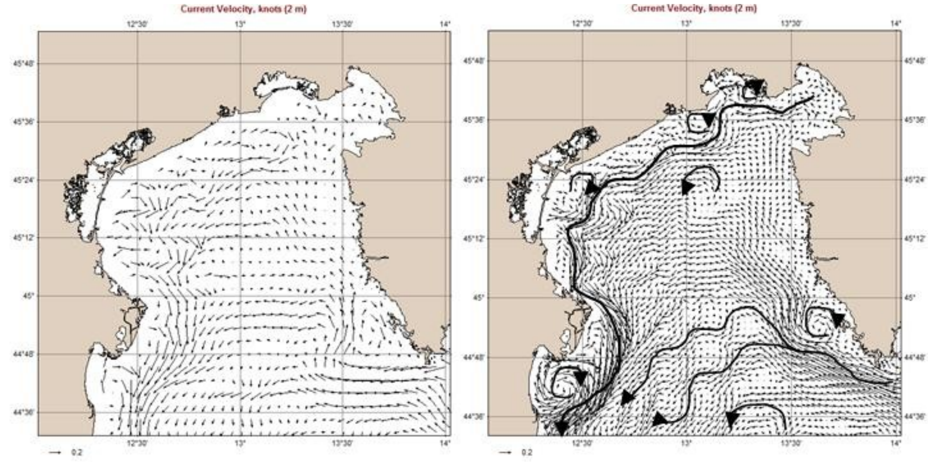

Figure 2 Comparison of the surface currents between the old (left) and new (right) model. The thick blak lines outline the features that become well defined when increasing the resolution.

Another important improvement of the new model is the introduction of realistic fresh water fluxes surface boundary conditions. The old model used only salt fluxes while the water fluxes did not produce volume changes. The new formulation of the boundary condition for *w* at the surface now reads:

$$w\Big|_{z=\eta} - \left(\frac{\partial \eta}{\partial t} + \bar{v} \cdot \nabla \eta \right)\Bigg|_{z=\eta} = \left(E - P - R \right)$$

where is the surface elevation, E, P, and R are the evaporation, precipitation and river runoff; *w* the vertical velocity and *v* the horizontal velocity field.

For the open boundary (the transect of latitude 39° N), a new condition on barotropic velocity has been implemented following Flather (1976) and Oddo and Pinardi (2007):

$$V = v^{ext} \pm \frac{\sqrt{gH}}{H}(\eta - \eta^{ext})$$

Where *V* is the normal component of the barotropic velocity at the open boundary, v^{ext} *and* ^{ext} are the barotropic normal velocity component and surface elevation of the nesting model, and is the free surface calculated by the nested model. This formulation of the barotropic velocity lateral boundary conditions is based on the mass conservation equation and guarantees consistency in the conservation of mass between the nesting and nested model.

Last, a new advection scheme following Estubier and Lévy (2000) was implemented in the new model in order to reduce the numerical overestimation of diffusion and to give more realistic representation of horizontal and vertical gradients.

3 Validation of the System

3.1 Delayed Mode Validation

The new model has been validated in terms of temperature and salinity from available XBTs and CTDs in the period between 2001 and 2007, and in terms of sea surface temperature using satellite data made available from CNR-ISAC, interpolated on a regular grid of about 5 km of horizontal resolution over the whole Adriatic sea. Here we show the validation for temperature and salinity for the year 2006, when a large amount of CTDs and XBTs data were available. In particular the images presented refer to 1249 CTD profiles sampled from January to December 2006 in the north west and south east of the Adriatic basin, as shown in figure 3

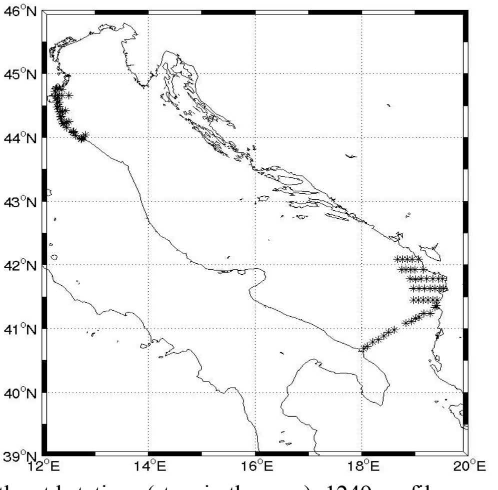

Figure 3: Location of the ctd stations (stars in the map): 1249 profiles are available, collected from January 2006 to December 2006

As figures 4 and 5 show, the new model decreases both the root mean square errors (RMSE) and the bias for what concerns salinity: both in the Montenegro-Albania and Emilia-Romagna region the new model system improves over the old one even if some discrepancies persist. For what concerns the temperature bias and RMSE in the Montenegro-Albanian region we also improve but not in the Emilia Romagna region. In this region in fact, despite the fact that the mean bias over the whole water column doesn't practically change (-0.3° C in both of the models), the RMSE of the new model is constantly higher.

The northern part of the Adriatic Sea does not improve its temperature RMSE also for the years from 2001 to 2005 and for 2007, showing a systematic, persistent error in the model in this region, probably connected to the Po river temperature waters influence that is not correctly represented in the model. On the other hands, the 2001-2005 validation shows that the new model improves in salinity over the whole Adriatic basin. Further investigations will have to be carried out for this temperature problem in the northern Adriatic Sea.

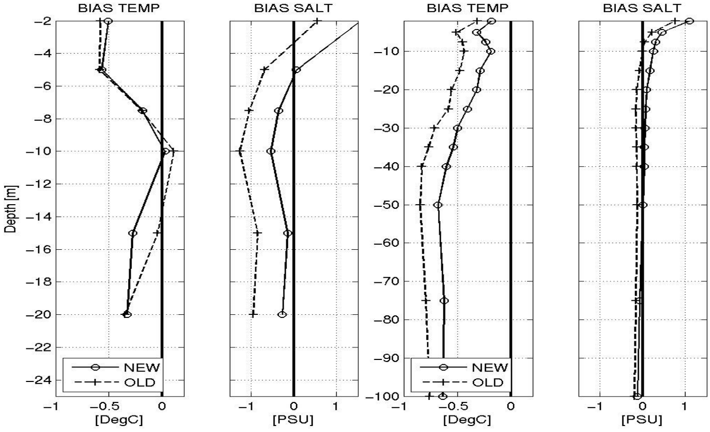

Figure 4: Comparison between the bias in temperature and salinity in the Emilia Romagna region (first two panels) and in the Albanian region (last two panels) for the period January-December 2006

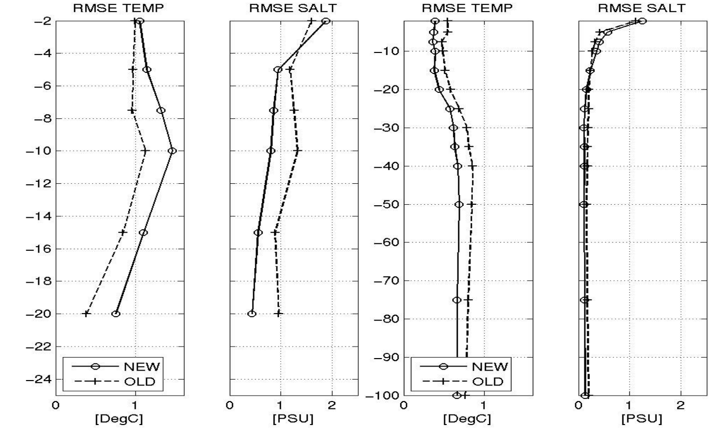

Figure 5: Comparison between the RMSE in temperature and salinity in the Emilia Romagna region (first two panels) and in the Albanian region (last two panels) for the period January-December 2006

3.2 Near Real Time Validation

A new procedure of near real time (NRT) validation of the model versus observations of a buoy located at 44°44.542'N 12°27.450' E, Bortoluzzi et al.(2006) is operational since April 2008 The procedure weekly downloads the data of temperature, salinity and currents computed hourly by the buoy, and then calculates the daily means, bias and RMSEs for each variable. Daily timeseries of the RMSEs and biases of the temperature (see figure 5), salinity and currents are produced every week, as well as daily maps of the means of the same variables in the area of interest showing the difference between the observed and the simulated data.

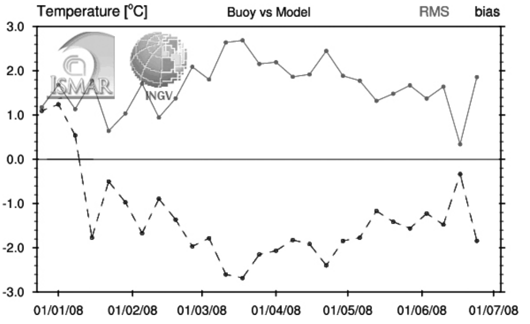

Figure 5: Timeseries of RMSE (solid line) and bias (dashed line) of temperature.

A similar procedure for the quality control of the sea surface temperature is running in pre-operational mode since June 2008, showing biases and RMSEs between the observed SST (satellite data are the same mentioned in paragraph 3.1) and the SST simulated by the model. The NRT validation is daily available on the web page http://gnoo.bo.ingv.it/afs/buoy.htm.

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